The Bohm Approach.

The Copenhagen and von Neumann formulations of quantum theory are non-deterministic. Both specify that human choices (about how to act) enter into the dynamics, but neither of these formulations specify the causal origins of these choices. The question thus arises: what determines these choices?

One possibility is that these choices arise in some yet-to-be-specified way from what we conceive to be the *idealike aspect of reality*. That option was pursued by Penrose, with his suggestion that our thoughts are somehow linked to Plato's world of ideal forms. Another -seemingly different – possibility is that there is a *more complete physical theory*, or *another physical process*, which involves physically described entities other than the smeared out structures that occur in the orthodox formulations, and that these *other physical elements* determine the features left undetermined in the orthodox formulations of quantum theory.

This second approach was developed by David Bohm. His formulation of quantum theory postulates, in effect, the existence of the old-fashioned world of classical physical theory. It is supposed to exist in *addition to the wave function of quantum theory.* This classical world, like that wave function, evolves in a way completely determined by what precedes it in time. Thus Bohm's theory reinstates determinism in a way compatible with the rules and predictions of quantum theory, though at the expense of abandoning locality: Bohm's theory entails strong, long-range action-at-a-distance.

One serious failing of Bohm's approach is that it was originally formulated in a non-relativistic context, and has yet to be – after half a century of diligent effort – extended to the most important domain in physics, namely the realm of quantum electrodynamics, which is the theory that covers the atoms our bodies are made of, along with the tables, chairs, automobiles, and computers that populate our daily lives. This deficiency means that Bohm's theory is, at present, an interesting curiosity, rather than a real physical theory.

Also, Bohm's theory, at least in its original form, is not really germane to the issue of consciousness. For Bohm's theory *successfully achieved its aim,* which was precisely to get rid of consciousness: i.e., to eliminate consciousness from the basic dynamics, just as classical physics had previously done.

Bohm recognized, later on, that some understanding of consciousness was needed, but he was led, instead, to the notion of an infinite tower of mechanical levels, each controlling the one below, with consciousness somehow tied to the mystery of the infinite limit.

Bohm's infinite-tower idea tends to negate the great achievement of the original theory, which was to reinstate physical determinism in a simple way. To examine this conceivable option of a *physical determinism* compatible with the empirical predictions of quantum theory it is instructive to examine Bohm's original deterministic model, in order to see how, within that deterministic framework, consciousness enters at the level of scientific practice.

As explained in the introductory section, scientific practice involves setting up experimental conditions that fulfill consciously experienced needs and objectives. In von Neumann's theory these consciously chosen actions influence the subsequent course of events in The Observed System, which, according to von Neumann's construction of quantum theory, is the brain of the human participant. A key point is that these choices, made by the experimenter about how he will act, are treated in von Neumann's theory, and also by Copenhagen quantum theory, as *input data*, to be fixed by the experimenter, without specifying how these choices are made. These choices are *treated* as free variables: they are the controllable input boundary conditions.

In Bohm's theory these choices is not free: freedom is an illusion. The apparently free choice is, at a deeper level, completely determined by *physical* conditions, just as it was in classical physics.

Nevertheless, the analysis of Heisenberg shows that, even within the context of Bohmian mechanics, the human observers can never determine, or *know*, which of the conceivable possible classical

Bohmiam worlds their experiences belong to. The Heisenberg Uncertainty Principle cannot be evaded: the most that the experiencers can ever actually know about the Bohmian classical world of which they are a putative part is represented by a quantum wave function.

This limitation *in human knowledge* is acknowledged by Bohm. Indeed, Bohm's theory leaves scientific practice the same as it is in the Copenhagen approach. This *equivalence at the practical level* of Bohm's model to the Copenhagen formulation means that in actual practice the unfillable gap in human knowledge mandated by the uncertainty principle is bridged by replacing, in the quantum dynamics, the *in-principle-unknowable information about the microscopic physical conditions* by *in-practice-controllable and knowable realities*, our conscious choices.

When solving a problem in physics there is always a question about which variables to use. At the level of practical science it is advantageous to use variables that are in actual practice controllable and knowable rather than variables that are in principle unknowable. Specifying an experientially controllable and knowable 'choice about how to act' places conditions on the in-principle-unknowable Bohmian classical world. These conditions permit predictions about future experiences to be deduced, without being blocked by the unknowability of the postulated "other" variables, which may not even exist. Why bring into science unknowable parameters, instead of variables that we can control and know, when we have equations, namely the equations that specify the effects of Processes **1** and **3**, that (1), bring controllable parameters directly into the description of dynamical process, and leave out the unknowable ones, and that (2), according to the unchallenged arguments of Heisenberg, tell us, in conjunction with Process **2**, all that we can ever learn (within the framework of the principles of physics) about the effects of our conscious choices upon our future experiences.

The advantages of using equations involving controllable and knowable parameters rather than unknowable ones are just as real in neuroscience as they are in atomic physics. Of what use are (highly nonlocal) deterministic equations that depend on the in-principle-unknowable motions of classically conceived calcium ions inside nerve terminals, instead of the statistical effects of our controllable and knowable choices?